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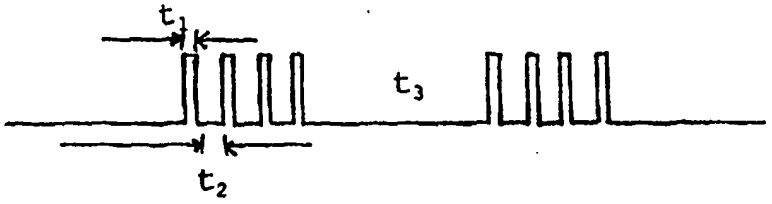
(54) Title: METHOD AND APPARATUS FOR ACOUSTIC CLEANING

(57) Abstract



The invention relates to a method and an apparatus for cleaning objects to be cleaned by means of sound wave vibrations. In the method, a sound wave burst of a preselected frequency and of preselected duration (t_1) is produced. The sound wave burst is directed to an object that is cleaned, in which connection, during said duration (t_1), the sound wave burst reaches the maximum loudness and is reduced to a preselected lower loudness. This sound wave burst can be repeated after a predetermined time interval (t_2). The sound wave burst is produced by an apparatus which comprises a feed system for compressed gas and a vibration part. The vibration part comprises a valve and a sonic horn. Sonic cleaning devices are commonly used in the process industry, where powdery particles are processed. The object of cleaning is to break the deposits formed by powders and to remove them from the processes.

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Method and apparatus for acoustic cleaning

The invention relates to a method for cleaning objects to be cleaned by means of sound wave vibrations. The invention also relates to an apparatus for cleaning objects to be cleaned by means of sound wave vibration.

Acoustic cleaning, which is also called sound sweeping, is a method which is used for cleaning of e.g. boilers, silos, cyclones, blowers, filter devices and the like. The acoustic cleaning method is fit for use in objects in which, for example, powdery materials are treated or in which, for example, soot or dust is produced as harmful by-products. Such particles readily form deposits which impede the flow of the process and weaken its performance.

An advantage of the acoustic cleaning method over different mechanical cleaning methods is the possibility of using it without interrupting the process. As a second significant advantage it may mentioned that the method is also capable of cleaning shadow areas and other areas difficult to reach. The method does not wear the objects to be cleaned, is easy to use, and its maintenance costs are low.

In the acoustic cleaning method, a sound wave is directed to the object to be cleaned, said sound wave transmitting a pressure shock to the particles to be loosened. In order to achieve a cleaning result, the force transmitted by a sound wave burst to each particle must be higher than the force which holds a particle attached to a base or particles attached to one another.

The sound wave burst needed for cleaning is provided by means of a diaphragm valve controlled by compressed gas and of a sonic horn, which form a vibration system. Connecting the compressed gas opens the diaphragm and a gas flow can enter the horn. After that, the pressure decreases while the gas discharges, causing

the diaphragm to close. The basic excitation of a sound wave burst arises from interrupting of the flow of the compressed gas. The thus produced frequency distribution includes a basic frequency and its harmonic multiple frequencies.

The basic frequency of the cleaning means is generally close to the resonant frequency of the vibration of the valve, whereby the horn may be caused to blare most easily. The basic frequency can be regulated by changing the dimensions of the sonic horn and the vibration frequency of the valve. The most suitable operation frequency depends on the object to be cleaned and on the quality of particles.

The most significant problem associated with the present-day acoustic cleaning methods which are in use is the considerable noise load caused by the apparatus. A typical noise level is 150 dB when the apparatus is in operation. In plants situated in densely populated areas, in particular, this restricts the use of the cleaning means to taking place only in the daytime. Similarly, a high noise level is harmful to the employees working in plants.

The object of the invention is to provide an improvement over the currently known method for acoustic cleaning and over the associated apparatus arrangements.

The objective of the invention is achieved by a method which is characterized in that, in the method, a sound wave burst of a preselected frequency is produced, a sound wave burst of preselected duration is directed to an object that is cleaned, in which connection, during said duration, the sound wave burst reaches the maximum loudness of the sound wave burst and is reduced from said maximum loudness to a preselected lower loudness, and said sound wave burst is repeated after a second predetermined time interval.

The apparatus in accordance with the invention is characterized in that the apparatus comprises means for producing a sound wave burst of a preselected frequency, and means for providing preselected duration for the sound wave burst and for repeating the sound wave burst after a preselected time interval.

When examining the operation of acoustic cleaning apparatus, it has been observed that the actual cleaning work takes place immediately after starting of the apparatus. In other words, applying long cleaning pulses is of no significant further benefit, but the same cleaning efficiency can be achieved with an operating time that is considerably shorter than that of present-day practice.

The principle of the method in accordance with the invention is that the operation of the cleaning apparatus is changed such that the duration of a pulse is shortened to about 10 % of the previous one, and these short pulses are repeated at predetermined time intervals. The noise load of the thus created cleaning cycle remains clearly lower than that of the conventional sonic cleaning methods. At the same time, the wear of the apparatus becomes slower.

The procedure in the most general embodiment of the method in accordance with the invention is as follows. First, a sound wave burst of a preselected frequency is produced. Second, a sound wave burst of preselected duration is directed to an object that is being cleaned, in which connection, during said duration, the sound wave burst has reached the maximum loudness of the sound wave burst and is reduced from said maximum loudness to a preselected lower loudness. Finally, said sound wave burst is repeated after a second predetermined time interval.

The duration of the sound wave burst is preferably chosen to be 5 – 15 ms. The sound wave burst is repeated, for example, at intervals of 1 – 10 s, preferably at intervals of 1 – 2 s. A suitable pause time depends on the application and is usually of the order of 1 – 60 min. The frequency of the sound wave burst is chosen as desired, preferably in the range of from 80 Hz to 500 Hz by changing the horn part of the apparatus.

The method and the apparatus in accordance with the invention provide a number of significant advantages. Instead of applying long sound pulses, the noise load of the environment can be considerably relieved by a shorter operating time. In addition,

cleaning efficiency is considerably improved. At the same time, the wear of the apparatus becomes slower since unnecessary operating time is eliminated.

The invention will be described in detail with reference to some preferred embodiments shown in the figures of the accompanying drawings, to which embodiments the invention is, however, not intended to be exclusively confined.

Figure 1 shows a sonic cleaning apparatus in accordance with the invention as a block diagram.

Figure 2 is a partial sectional view of a sonic horn part of the acoustic cleaning apparatus in accordance with the invention seen from the side.

Figure 3 shows the sonic horn part of Figure 2 viewed from behind.

Figure 4 shows graphically the development of sound pressure as a function of time.

Figure 5A shows a sound cycle of a cleaning apparatus known from the state of the art, and Figure 5B shows a sound cycle in accordance with the invention.

Figure 6 shows a disc by which a solenoid valve can be controlled very quickly, as a view seen from the top.

Figures 7A and 7B show two advantageous modes of producing a sound wave burst by means of rapid gas expansion.

The block diagram of Fig. 1 shows the operation principle and basic components of the apparatus. The device comprises a feed system 11 for compressed gas, a spherical valve 12, a filter 13, a pressure controller 14, a solenoid valve 15, and a horn part 16. Compressed gas is fed into the system through the spherical valve 12, the filter 13 and the pressure controller 14.

Figs. 2 and 3 show the horn part 16 in more detail. The horn part 16 comprises four basic components, a horn 17, a frame 18, a cover 19, and a diaphragm 20. The cover 19 is provided with holes 22 for fastening members 21. The cover 19 is fastened to the frame 18 by means of the fastening members 21.

When compressed gas is applied to the solenoid valve 15, the diaphragm 20 of the valve opens and the gas can enter the sonic horn 17. A subsequent decrease in pressure causes the diaphragm 20 to close and the sound wave to be interrupted. A rise in pressure after that opens the diaphragm 20 again after a few milliseconds, and the thus produced vibration generates a sound wave burst needed in cleaning.

Fig. 4 shows a measuring curve of the development of the sound pressure as a function of time during about 32 ms. In the situation of the figure, the device is switched on at the point of time 0 s and the sound pressure curve starts to grow at the point of time about 7 ms. In the embodiment in accordance with the invention, the sound pressure curve is interrupted, for example, after the duration of 15 ms.

Fig. 5A illustrates the present state of sonic cleaning technology. According to the present state of the art, the apparatus applies long sound wave bursts in order to achieve a cleaning result. In Fig. 5A, the operation time, i.e. the working time, of the apparatus is denoted with t_1 and the time between the cleaning pulses, i.e. the pause time, is denoted with t_3.

By means of the method in accordance with the invention, as shown in Fig. 5B, the duration of the sound wave burst, i.e. the working time t_1, is shortened to a considerable extent. A number of these short pulses are applied at time intervals of t_2. After applying a pulse sequence, there is a pause for the duration of the pause time t_3. Repeating of a number of short cleaning pulses instead of one long pulse provides significantly better cleaning efficiency as compared with the present-day technique.

Fig. 6 shows a disc 23 used for control of the sonic cleaning apparatus, said disc having holes 24, preferably round holes, situated in the periphery of the circle. By using discs 23 rotating in opposite directions, the solenoid valve 15 can be controlled much more quickly than by the present-day technique.

In the embodiments shown in Figs. 7A and 7A, the sound excitation is produced by means of explosion-like combustion. In the embodiment shown in Fig. 7A, the burning substance is an inflammable gas, which is passed from a feed line 28 so as to be mixed with the compressed air passed along a feed line 27. Ignition takes place in an ignition chamber 26 at a precisely predetermined instant, for example, by means of an electric spark. The sound excitation is produced in a vibration chamber 25. In the case of Fig. 7B, the operating substance is an explosive, for example, gunpowder or another substance that behaves in a similar way, in which case ignition is carried out by means of a firing mechanism 29. In both embodiments, sound making and the pause times are determined precisely in advance.

Only some advantageous embodiments of the invention have been described above, and it is obvious to a person skilled in the art that numerous modifications may be made to them within the inventive idea set forth in the accompanying claims.

Claims

1. A method for cleaning objects to be cleaned by means of sound wave vibrations, **characterized** in that, in the method,

(a) a sound wave burst of a preselected frequency is produced,

(b) a sound wave burst of preselected duration (t_1) is directed to an object that is cleaned, in which connection, during said duration (t_1), the sound wave burst has reached the maximum loudness of the sound wave burst and is reduced from said maximum loudness to a preselecfed lower loudness, and

(c) said sound wave burst is repeated after a second predetermined time interval (t_2).

2. A method as claimed in claim 1, **characterized** in that as the duration (t_1) of the sound wave burst is chosen 5—15 ms.

3. A method as claimed in claim 1 or 2, **characterized** in that said sound wave burst is repeated at intervals of 1—10 s, preferably at intervals of 1—2 s.

4. A method as claimed in any one of claims 1 to 3, **characterized** in that, in the method, the use of the sound wave burst is interrupted for a period of 1—60 minutes.

5. A method as claimed in any one of claims 1 to 4, **characterized** in that, in the method, the frequency of the sound wave burst is chosen from the range of 80 Hz – 500 Hz.

6. A method as claimed in any one of claims 1 to 5, **characterized** in that the sound wave burst is produced by means of compressed gas.

7. A method as claimed in any one of claims 1 to 5, **characterized** in that the sound wave burst is produced by means of an inflammable gas mixture.

8. A method as claimed in any one of claims 1 to 5, **characterized** in that the sound wave burst is produced by means of an explosive, preferably gunpowder.

9. An apparatus for cleaning objects to be cleaned by means of sound wave vibration, **characterized** in that the apparatus comprises means (11-16) for producing a sound wave burst of a preselected frequency, and means (15, 23) for providing preselected duration for the sound wave burst and for repeating the sound wave burst after a preselected time interval.

10. An apparatus as claimed in claim 9, **characterized** in that the apparatus comprises a chamber (26) and gas feed lines (27,28) for providing an inflammable gas mixture into the chamber (26).

11. An apparatus as claimed in claim 9, **characterized** in that the apparatus comprises a chamber (26) and a firing mechanism (29) which is arranged to fire an explosive, preferably gunpowder, placed in the chamber (26).

12. An apparatus as claimed in any one of claims 9 to 11, **characterized** in that a valve (15) is controlled by means of discs (23) rotating in opposite directions, in the periphery of which discs there are holes (24), and the speed of rotation of which discs can be regulated.

13. An apparatus as claimed in claim 12, **characterized** in that the holes (24) are round.

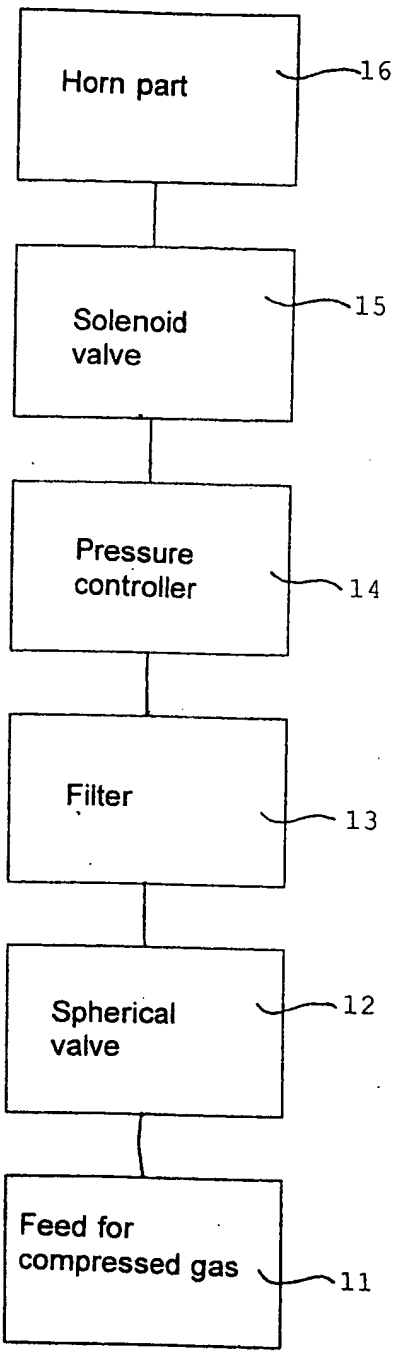
Horn part
16
Solenoid valve
15
Pressure controller
14
Filter
13
Spherical valve
12
Feed for compressed gas
11

FIG. 1

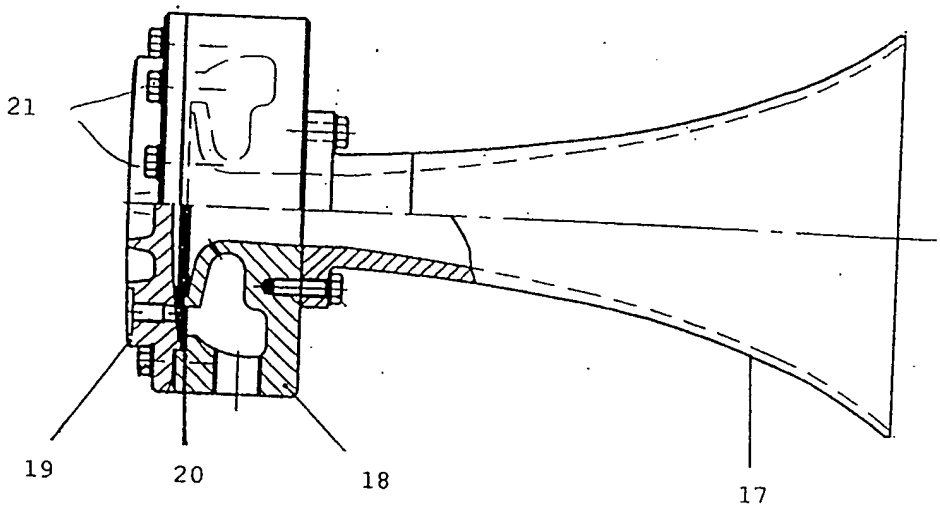

FIG. 2

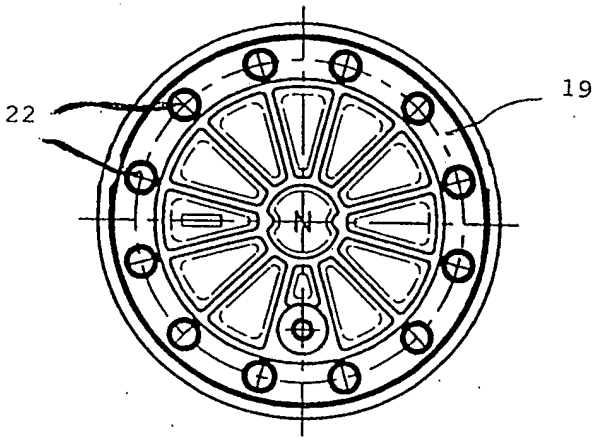

FIG. 3

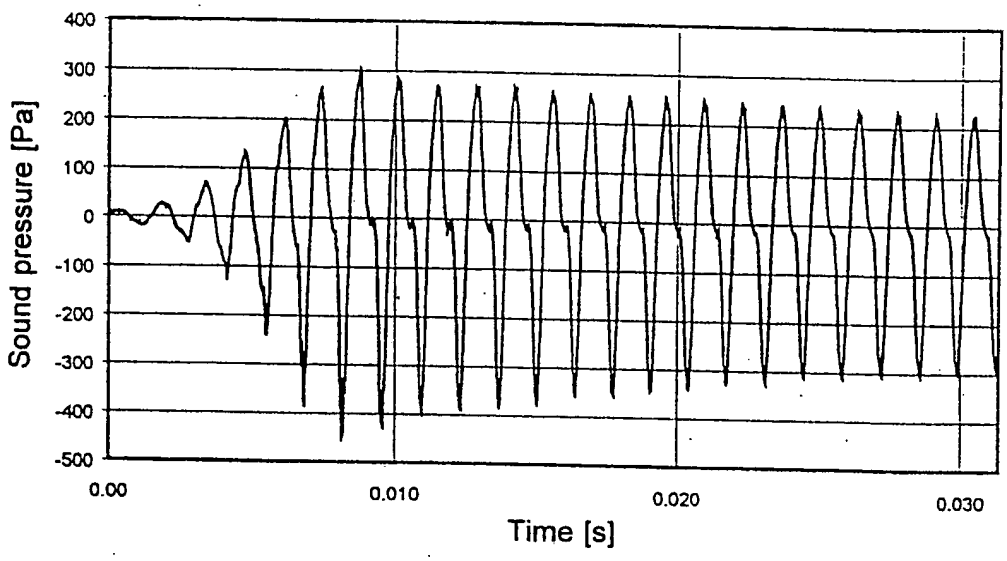
400
300
200
100
0
-100
-200
-300
-400
-500
Sound pressure [Pa]
0.00
0.010
0.020
0.030
Time [s]

FIG. 4

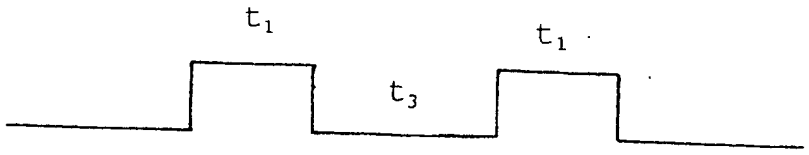

FIG. 5 A
PRIOR ART

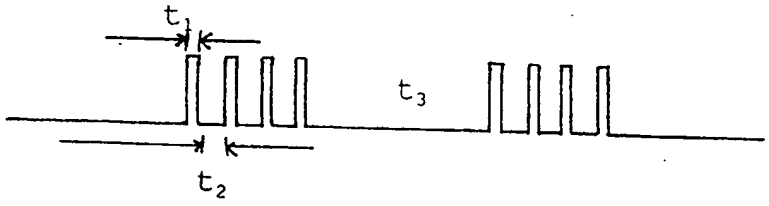

FIG. 5 B

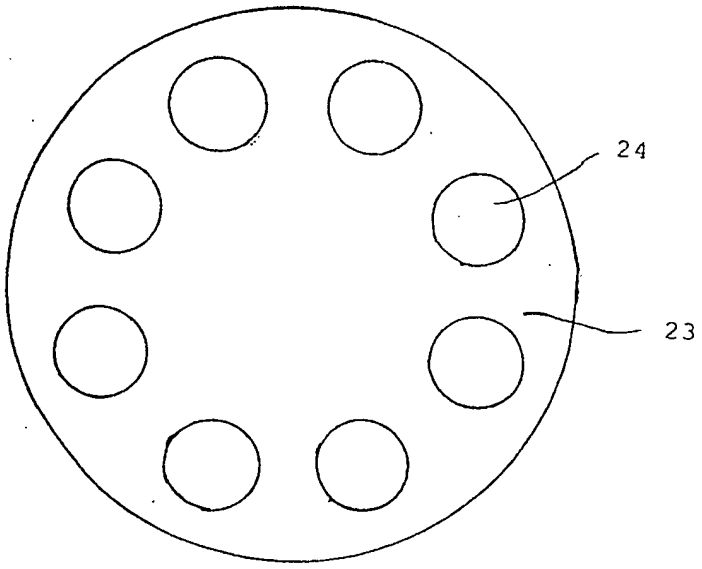

FIG. 6

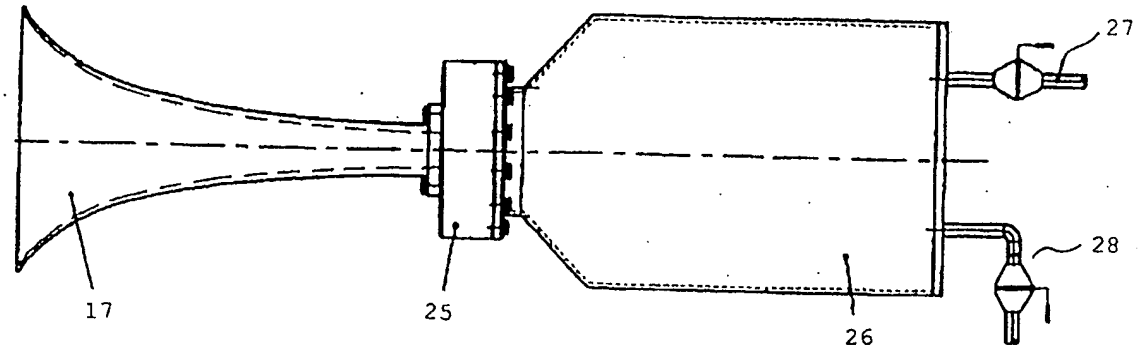

FIG. 7A

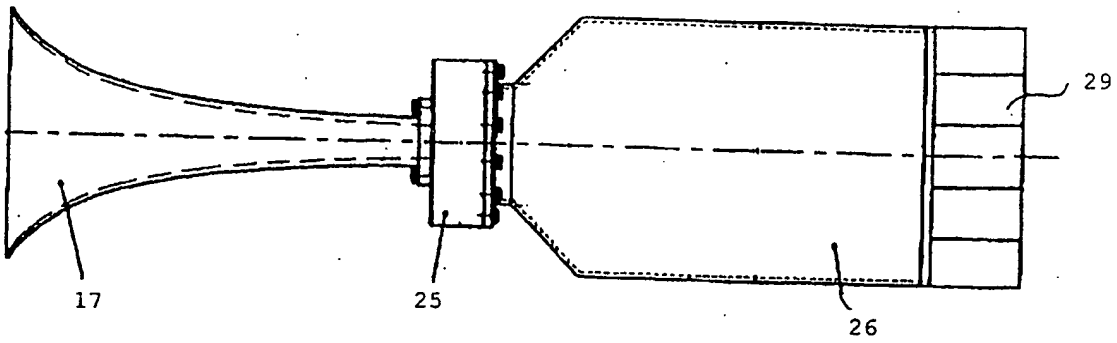

FIG. 7B

INTERNATIONAL SEARCH REPORT

International application No.
PCT/FI 98/00423

A. CLASSIFICATION OF SUBJECT MATTER

IPC6: B08B 5/00, B08B 7/02 // B08B 9/08, G10K 9/00
According to International Patent Classification (IPC) or to both national classification and IPC

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Minimum documentation searched (classification system followed by classification symbols)

IPC6: B08B, G10K, B06B, F28G, F15B, F23J, B01D

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

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Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

WPI

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 3457893 A (J.P. LAVALIER), 29 July 1969 (29.07.69), column 1, line 37 - line 63; column 2, line 44 - column 3, line 75, figures 1-3	1-6,9
Y		7-8,10-13
	--	
X	DE 4341996 A1 (ABB MANAGEMENT AG), 14 June 1995 (14.06.95), column 2, line 46 - column 4, line 2, figure 1	1,4,5,6,9
Y		7-8,10-13
	--	

[X] Further documents are listed in the continuation of Box C. [X] See patent family annex.

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Date of the actual completion of the international search	Date of mailing of the international search report
17 Sept 1998	21 -09- 1998
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International application No.
PCT/FI 98/00423

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 4923374 A (LUNDIN ET AL), 8 May 1990 (08.05.90), column 1, line 22 - line 35; column 6, line 52 - line 64	1,4,6,9
Y		7-8,10-13
	--	
X	WO 8201328 A1 (EKSTRÖMS VÄRMETEKNISKA AB), 29 April 1982 (29.04.82), page 3, line 35 - page 4, line 14	1,5,6,9
Y		7-8,10-13
	--	
X	GB 2125314 A (THE BABCOCK & WILCOX COMPANY), 7 March 1984 (07.03.84), page 1, line 29 - line 60; page 2, line 59 - line 86, figures 1-4	1,5,6,9
Y		7-8,10-13
	--	
X	US 4359962 A (OLSSON ET AL), 23 November 1982 (23.11.82), column 3, line 17 - line 22; column 5, line 54 - line 68	1,6,9
Y		7-8,10-13
	--	
Y	US 5353721 A (MANSOUR ET AL), 11 October 1994 (11.10.94), figure 1, abstract	7,10
	--	
Y	Derwent's abstract, No K4074 E/31, week 8231, ABSTRACT OF SU, 871186 (KONDRATEV VI), 9 October 1981 (09.10.81)	7,10
	--	
Y	US 3233694 A (W.L. ROEVER), 8 February 1966 (08.02.66)	8,11
	--	

INTERNATIONAL SEARCH REPORT

International application No.
PCT/FI 98/00423

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	DE 3821351 A1 (LATOSCHINSKI, HEINZ-JüRGEN), 28 December 1989 (28.12.89), figures 1-2, abstract --	12-13
A	10 45292 A2 (KOCKUMATION AB), 3 February 1982 (03.02.82), figure 1, abstract --	1-13
A	WO 8203803 A1 (INFRASONIK AB), 11 November 1982 (11.11.82), figure 1, abstract -- --------	1-13

INTERNATIONAL SEARCH REPORT

Information on patent family members

27/07/98

International application No.
PCT/FI 98/00423

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
US 3457893 A	29/07/69	BE 702714 A	16/02/68
		BE 708653 A	02/05/68
		CH 479325 A	15/10/69
		CH 503208 A	15/02/71
		FR 1548214 A	29/11/68
		GB 1179432 A	28/01/70
		GB 1179433 A	28/01/70
		NL 6711229 A	16/02/68
		US 3487609 A	06/01/70
DE 4341996 A1	14/06/95	GB 2290829 A,B	10/01/96
		GB 9424893 D	00/00/00
		JP 7189735 A	28/07/95
		US 5758486 A	02/06/98
US 4923374 A	08/05/90	EP 0302899 A,B	15/02/89
		SE 457822 B,C	30/01/89
		SE 8605104 A	29/05/88
		WO 8803995 A	02/06/88
WO 8201328 A1	29/04/82	DK 152412 B,C	29/02/88
		DK 250482 A	03/06/82
		EP 0069741 A,B	19/01/83
		FI 71622 B,C	10/10/86
		FI 823866 A	11/11/82
		SE 425597 B,C	18/10/82
		SE 8007150 A	14/04/82
GB 2125314 A	07/03/84	AU 1490183 A	26/01/84
		BE 897309 A	14/11/83
		BR 8303623 A	12/06/84
		DE 3321455 A	19/01/84
		FI 832041 A	20/01/84
		FR 2530162 A	20/01/84
		JP 59029018 A	16/02/84
		SE 8303812 A	20/01/84
US 4359962 A	23/11/82	AT 4662 E,T	15/09/83
		CA 1146663 A	17/05/83
		DE 2926554 A,C	24/01/80
		DK 154110 B,C	10/10/88
		DK 270779 A	04/01/80
		EP 0006833 A,B	09/01/80
		FI 63871 B,C	31/05/83
		FI 792037 A	04/01/80
		FR 2430270 A,B	01/02/80
		GB 2033130 A,B	14/05/80
		JP 55039291 A	19/03/80
		SE 446157 B,C	18/08/86
		SE 7905616 A	04/01/80
		SU 1240370 A	23/06/86
		US 4517915 A	21/05/85

INTERNATIONAL SEARCH REPORT

Information on patent family members

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International application No.
PCT/FI 98/00423

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
US 5353721 A	11/10/94	AT 165999 T	15/05/98
		AU 6416994 A	24/10/94
		CN 1120319 A	10/04/96
		CZ 9502515 A	17/04/96
		DE 69410257 D	00/00/00
		EP 0691881 A,B	17/01/96
		SE 0691881 T3	
		HU 76199 A	28/07/97
		HU 9502823 D	00/00/00
		PL 314236 A	02/09/96
		WO 9422559 A	13/10/94
		US 5197399 A	30/03/93
US 3233694 A	08/02/66	NONE	
DE 3821351 A1	28/12/89	NONE	
10 45292 A2	03/02/82	NONE	
WO 8203803 A1	11/11/82	EP 0077364 A,B	27/04/83
		SE 0077364 T3	
		JP 58500725 T	06/05/83
		US 4624220 A	25/11/86